National Aeronautics and Space Administration

Humans to Mars:
HEOMD and MEPAG

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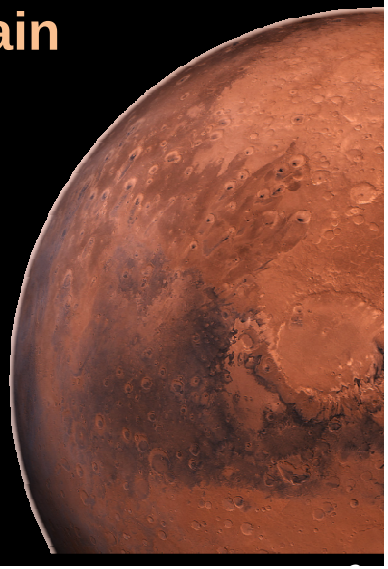
NASA Human Exploration and Operations Mission Directorate

National Aeronautics and Space Administration

- **NASA Mars Focus**
  - NASA's singular vision
  - Asteroid Retrieval Mission (ARM)
  - Global Exploration Roadmap
- **SMD + HEOMD + STMD**
  - Historical Progress
  - Mars 2020
  - Beyond
- **Strategic Knowledge Gaps**
  - MEPAG contribution and future action
- **Human Exploration and MEPAG – turning up the gain**



For Human Exploration, All Roads Lead to Mars

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- **NASA's vision:**
  - To reach for new heights and reveal the unknown so that what we do and learn will benefit all humankind
- **Why is Mars the new height?**
  - It is the only destination if humanity is to leave the cradle of Earth
- **How do we get to Mars?**
  - Through science, technology, commercial, international and human endeavors

The Science Road to Mars: Charting the Course

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Identify & Solve Challenges

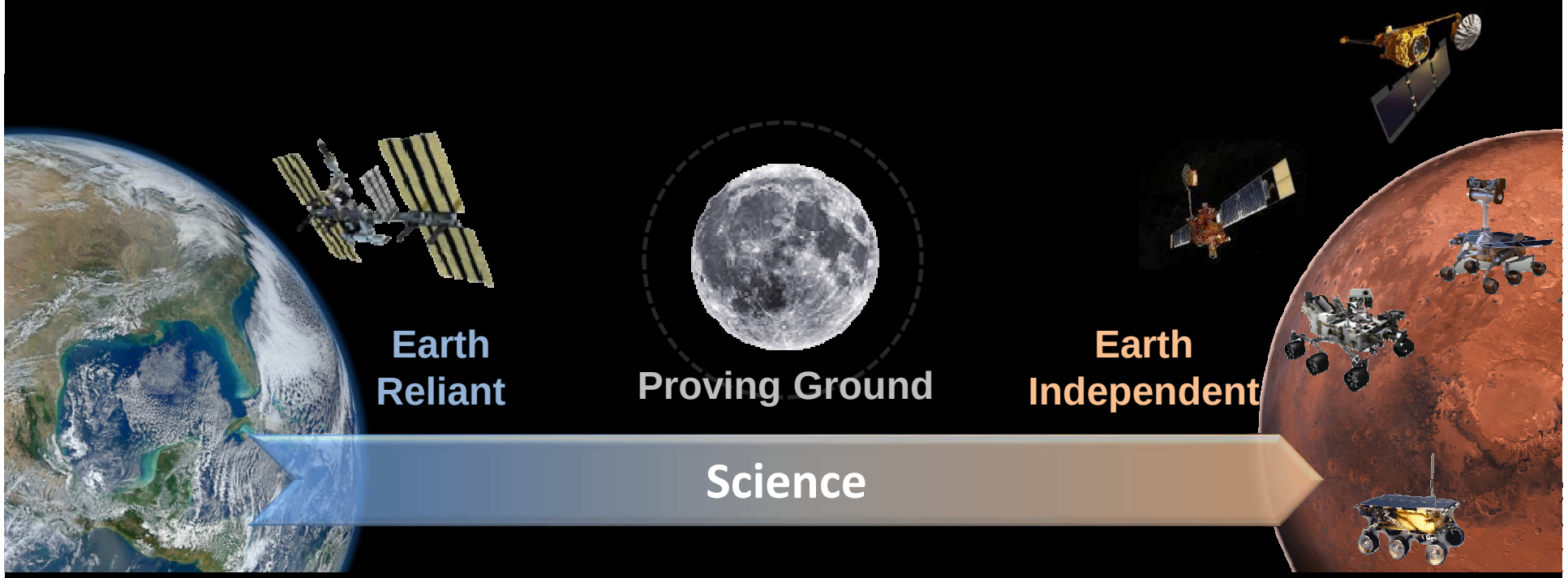
How does weightlessness affect human and physical processes?

Learn to Live & Work

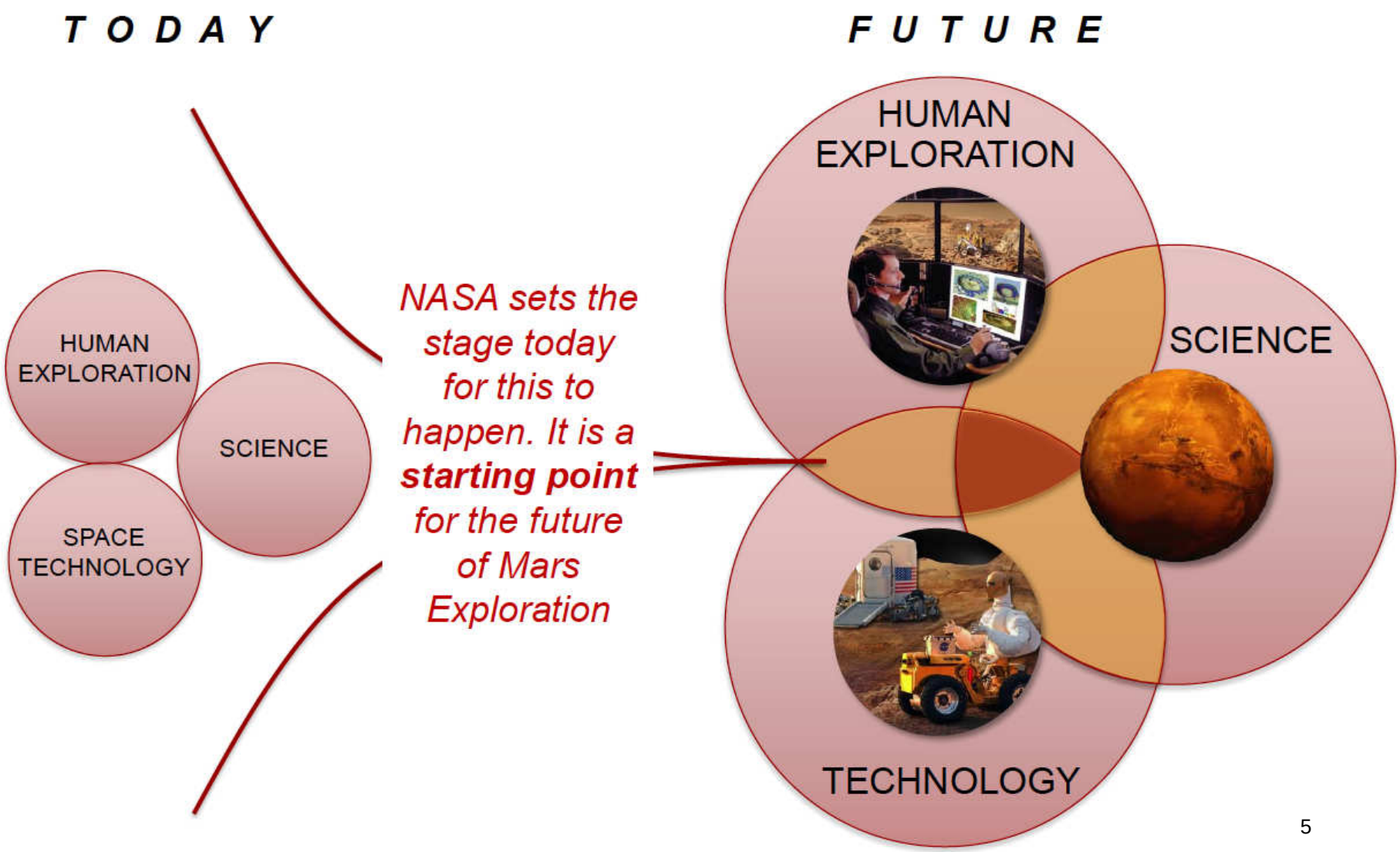
How do radiation and isolation affect human ability to live and work?

Explore & Pioneer

What's the environment and how does it impact human habitability?



Vision Basis for Cross Cutting Mars Exploration



HUMAN EXPLORATION

NASA's Path to Mars

EARTH RELIANT

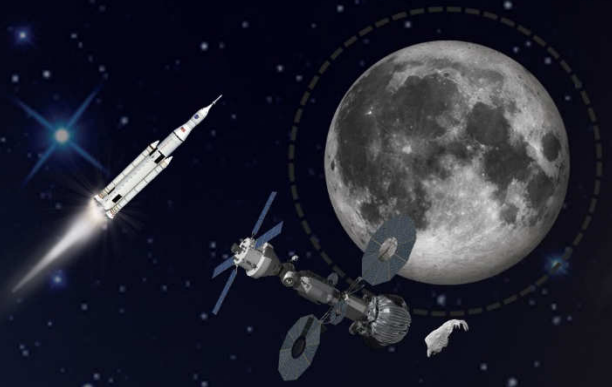
MISSION: 6 TO 12 MONTHS
RETURN TO EARTH: HOURS

Mastering fundamentals aboard the International Space Station

U.S. companies provide access to low-Earth orbit

PROVING GROUND

MISSION: 1 TO 12 MONTHS
RETURN TO EARTH: DAYS

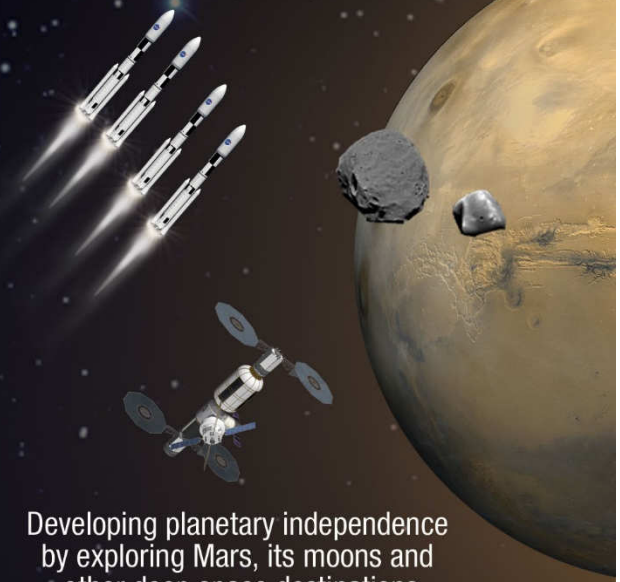


Expanding capabilities by visiting an asteroid redirected to a lunar distant retrograde orbit

The next step: traveling beyond low-Earth orbit with the Space Launch System rocket and Orion spacecraft

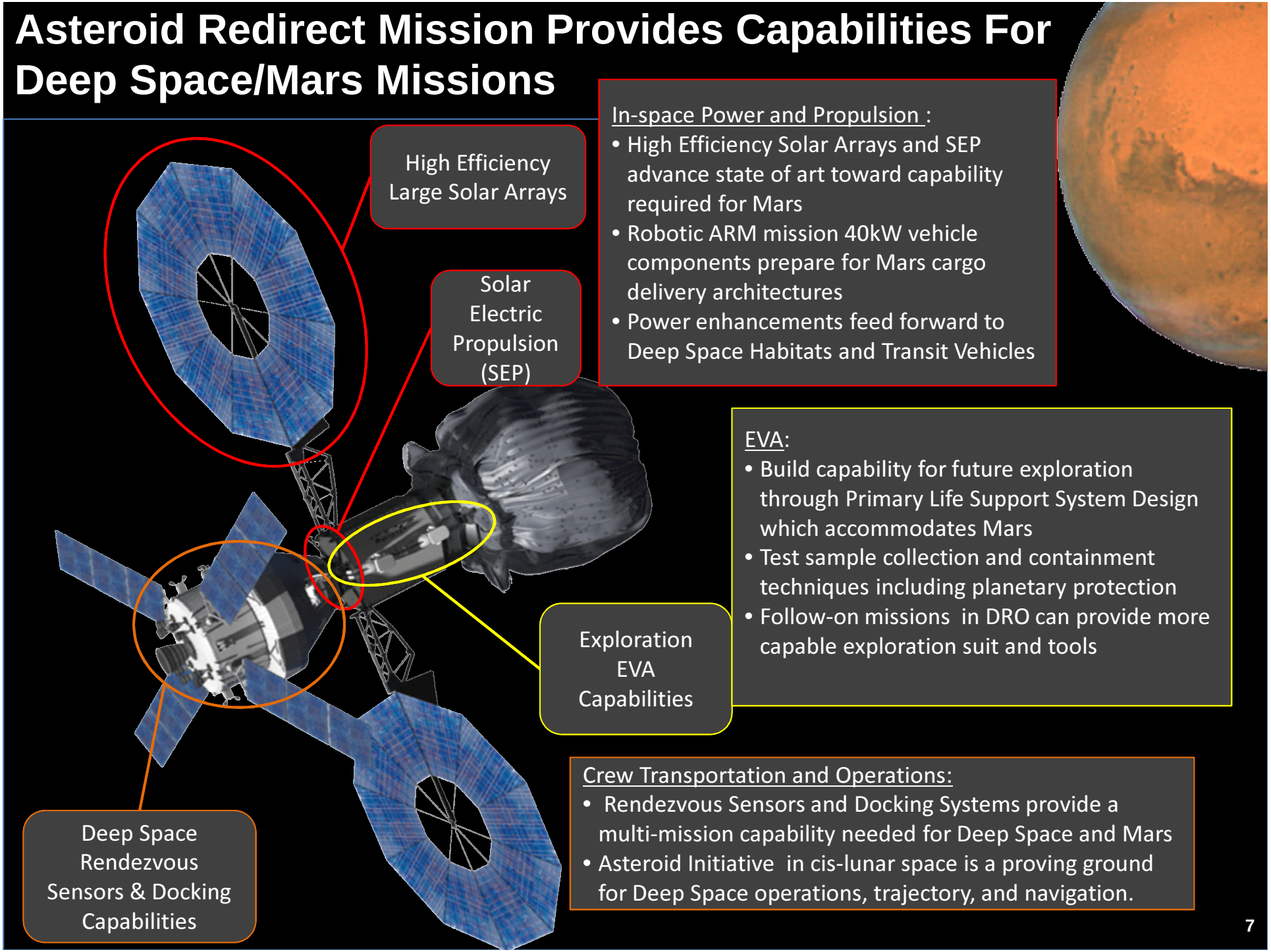
MARS READY

MISSION: 2 TO 3 YEARS
RETURN TO EARTH: MONTHS



Developing planetary independence by exploring Mars, its moons and other deep space destinations

Asteroid Redirect Mission Provides Capabilities For Deep Space/Mars Missions



<u>In-space Power and Propulsion</u> :

- High Efficiency Solar Arrays and SEP advance state of art toward capability required for Mars
- Robotic ARM mission 40kW vehicle components prepare for Mars cargo delivery architectures
- Power enhancements feed forward to Deep Space Habitats and Transit Vehicles

<u>EVA</u>:

- Build capability for future exploration through Primary Life Support System Design which accommodates Mars
- Test sample collection and containment techniques including planetary protection
- Follow-on missions in DRO can provide more capable exploration suit and tools

<u>Crew Transportation and Operations:</u>

- Rendezvous Sensors and Docking Systems provide a multi-mission capability needed for Deep Space and Mars
- Asteroid Initiative in cis-lunar space is a proving ground for Deep Space operations, trajectory, and navigation.

Global Exploration Roadmap

2013 2020 2030

International Space Station

General Research and Exploration Preparatory Activities

Note: ISS partner agencies have agreed to use the ISS until at least 2020.

Commercial or Government Low-Earth Orbit Platforms and Missions

Robotic Missions to Discover and Prepare

LADEE
Luna-25
Chandrayaan-2
Luna-26
Luna 27
RESOLVE
SELENE-2
Luna 28/29
SELENE-3
Rosetta
Hayabusa2
OSIRIS-REx
Apophis
MAVEN
ISRO Mars
ExoMars
InSight
ExoMars
Mars 2020
JAXA Mars Precursor

Mars Sample Return and Precursor Opportunities

Human Missions Beyond Low-Earth Orbit

Explore Near-Earth Asteroid

Extended Duration Crew Missions

Humans to Lunar Surface

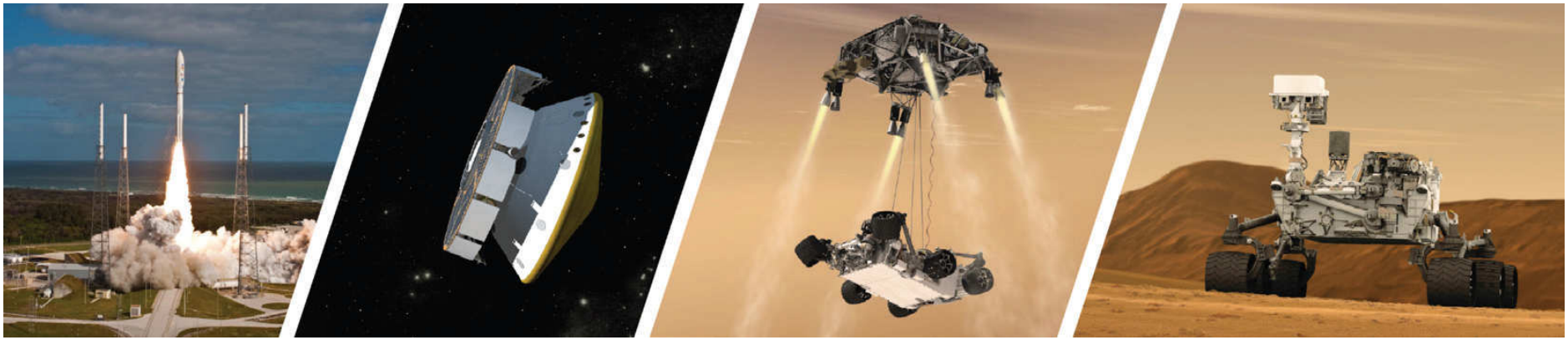
Missions to Deep Space and Mars System

Sustainable Human Missions to Mars Surface

Collaboration Among SMD, HEOMD and STMD

- **HEOMD (then HEDS) participated in the formation of MEPAG and the creation of the first MEPAG Goals/Objectives/Investigations document**
- **Continuous Human Exploration representation on MEPAG Goals committee**
- **Human Exploration participation in Mars Odyssey, Phoenix, Curiosity**
- **MEPAG inputs into Strategic Knowledge Gaps (SKGs)**
- **Space Technology Mission Directorate (STMD) a relatively new, but important player**

Mars 2020
Collaboration Among SMD, HEOMD and STMD

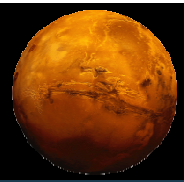


Mars 2020 will seek signs of past life on Mars, collect and store a set of soil and rock samples that could be returned to Earth in the future, and test new technology to benefit future robotic and human exploration of Mars.

HEOMD / SMD / STMD are jointly sponsoring investigations to address high priority strategic knowledge gaps and technology development objectives for Human Exploration

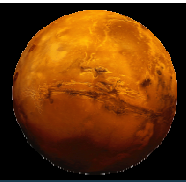
- Mars Entry, Descent and Landing Instrumentation (MEDLI) to refine atmospheric entry models to inform future landing system design
- Exploration technology payloads that make significant progress towards filling at least one major Strategic Knowledge Gap.

Strategic Knowledge Gaps



- **A Strategic Knowledge Gap (SKG) is an unknown or incomplete data set that contributes risk or cost to future human Mars missions**
  - **Apollo example – Footpads oversized due to poor knowledge of lunar soil bearing strength**
- **SKGs are not unique to human exploration; all NASA missions are designed based upon what is It is known and what is not.**
- **Science measurements are the greatest source of strategic Knowledge that has benefitted future human Mars exploration.**

The SKG Continuum-
Robotic Mission Contributions to Date



Mission	Launched	Country	Imagery	Global Imagery	High-resolution Imagery	Topography	Detailed Digital Elevbation Maps	Magnetic Field Measurement	Atmospheric Composition	Atmospheric Pressure, Temperature, Density	Global Gravity Mapping	Global Surface Composition Mapping	Detailed Soil Composition and Chemistry	Dust Characterizatin and Chemistry	Surface engineering properties	Particle Size and Shape	Surface Mobility Operations	Radiation Environment	Resource Identification and Mapping
Mariner 4	1964	USA	✔					✔										✔	
Mariner 6/7	1969	USA	✔																
Mars 3	1971	USSR				✔			✔	✔									
Mariner 9	1971	USA		✔							✔								
Mars 5/6	1973	USSR							✔	✔						✔			
Viking 1/2	1975	USA			✔					✔			✔		✔				
Mars Global Surveyor	1996	USA			✔	✔	✔	✔			✔	✔							
Pathfinder	1996	USA								✔			✔				✔		
Odyssey	2001	USA										✔						✔	✔
Mars Express	2003	ESA				✔						✔							
MER (Spirit/Opp'y)	2003	USA												✔	✔		✔		
MRO	2005	USA		✔	✔					✔	✔	✔							✔
Phoenix	2007	USA								✔	✔		✔			✔			✔
MSL (Curiosity)	2011	USA							✔				✔					✔	
Mangalyaan	2013	India																	
MAVEN	2013	USA																	

The SKG Continuum- What's Left to Know?

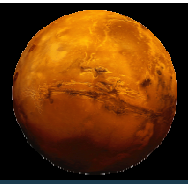
- **For the past 50 years, robotic missions have contributed data that reduces the risks of future human Mars exploration**

No data,
Most "unknowns"

No unknown data sets,
Planet completely characterized

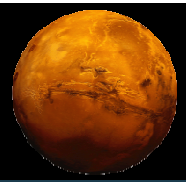
- **There's more to know, but we're well on our way**

Current Mars Strategic Knowledge Gaps (SKG's) 1/4



- Mars Atmosphere
  - Upper atmosphere global temperature field
  - Upper atmosphere global aerosol profiles and properties
  - Upper atmosphere Global wind and wind profiles
  - Orbital particulate environment
  - Lower atmosphere- global surface pressure; local weather
  - Lower atmosphere- surface winds
  - Lower atmosphere – EDL profile
  - Lower atmosphere – electrification
- Landing Site Characterization
  - Landing Site Hazards
  - Regolith physical properties and structure
  - Landing site selection
  - Surface trafficability

Mars Strategic Knowledge Gaps (SKG's) 2/4



- Contamination
  - Back Contamination to Earth:
  - - Mars Biohazards
  - Forward Contamination to Mars:
  - -Identify and map special regions
  - -Microbial survival, Mars conditions
- Crew Health
  - -Human Health & Performance
  - - Dust toxicity
- Dust Effects
  - -Dust physical, chemical and electrical properties
  - -Regolith physical properties and structure

Mars Strategic Knowledge Gaps (SKG's) 3/4

- ISRU Resource Potential

  Atmospheric ISRU:

  -Dust physical, chemical and electrical properties

  -Dust column abundances

  -Trace gas abundances

  Surface ISRU:

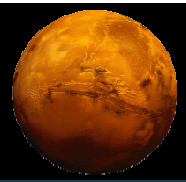
  -Hydrated mineral compositions

  -Hydrated mineral occurrences

  -Shallow water ice composition and properties

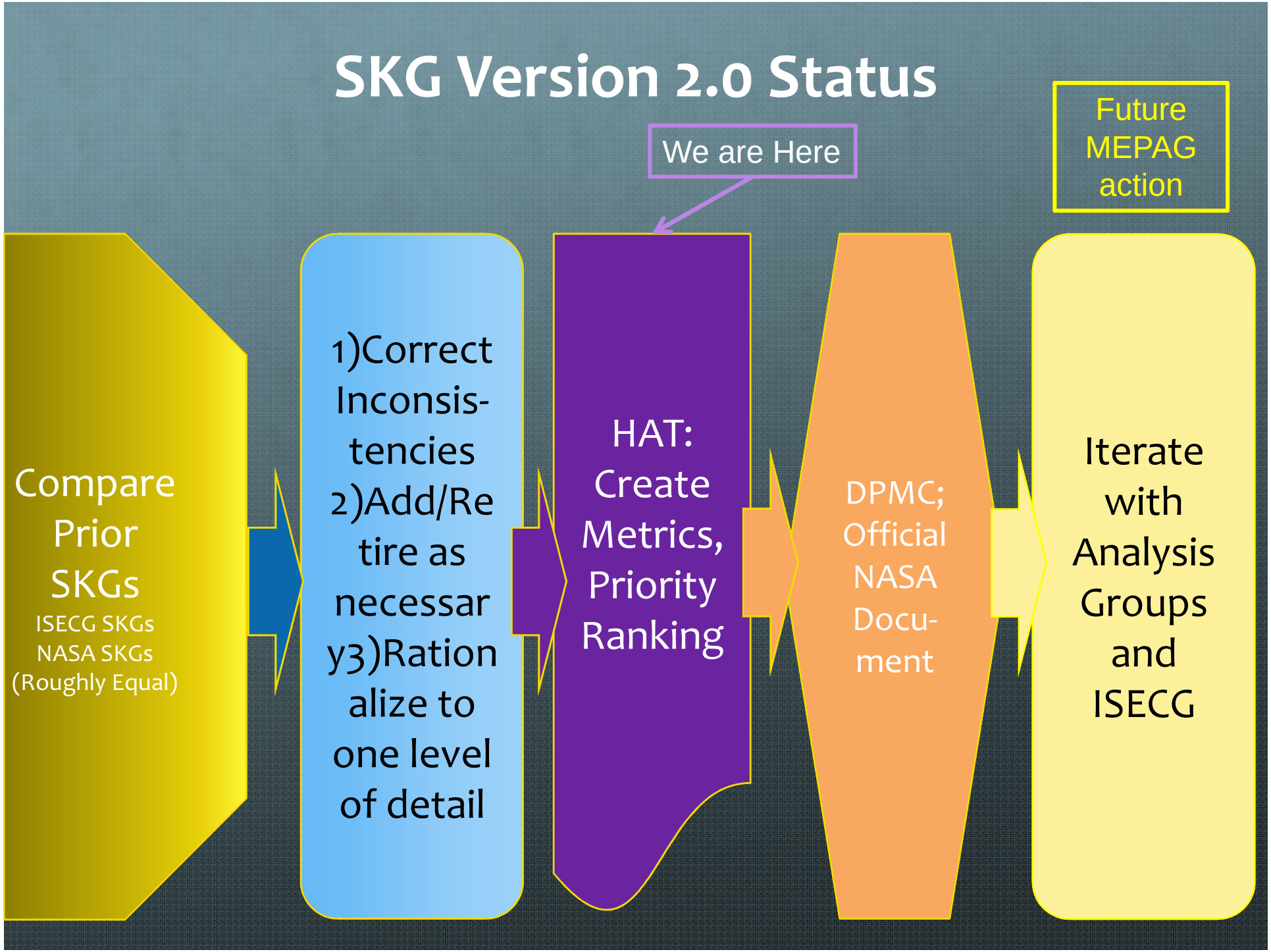
  -Shallow water ice occurrences

Mars Strategic Knowledge Gaps (SKG's) 4/4

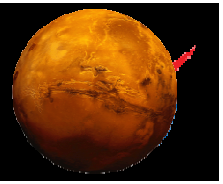


- Environment & Effects Radiation
  - -Simultaneous spectra of solar energetic particles in space and in the surface.
  - -Spectra of galactic cosmic rays in space
  - -Dust Effects on Engineered Systems
- Phobos/ Deimos
  - -Surface composition
  - -Surface operations
  - -Electric and plasma environments
  - -Gravitational fields
  - -Regolith properties
  - -Thermal environment

SKG Version 2.0 Status



Human Exploration and MEPAG – turning up the gain



- **Exploration Chief Scientist**
- **MEPAG Goals Committee**
  - **Human Exploration Science**
  - **Human Exploration Engineering**
  - **Exploration Technology**